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ORIGINAL RESEARCH PAPER

The variation of the onset of *Betula pendula* (Roth.) flowering in Rzeszów, SE Poland: fluctuation or trend?

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Abstract

The global rise in air temperature has major implications for ecosystems, populations, ecology of many living organisms, public health as well as economy. Plants, like silver birch (*Betula pendula* Roth.), strongly respond to the climatic variation. Therefore, the species is a good indicator of the global climate change, especially warming. The phenological observation was undertaken to verify the hypothesis on an acceleration of the start of *Betula pendula* pollen release in the season. The investigations were carried out in 2000–2015 (16 years) in the Rzeszów area, SE Poland. On average, *Betula pendula* started to pollinate in the middle of April; the difference between the earliest and latest dates was nearly 1 month. The full pollination started on 18 April, on average. The timing of pollination strongly depended on the course of weather in February and March. The most crucial was temperature in the first half of March. Considering the synergistic impact of meteorological parameters, the most important were temperature and rainfall in January and February, rainfall in March and temperature just before the pollination. It was found that North Atlantic Circulation influenced pollen release in *Betula pendula*. The positive North Atlantic Oscillation in March and in December–March periods resulted in pollination onset. Tendency towards warmer average annual temperature was recorded, however the timing of phenophases did not follow it. Despite the strong relationship with temperature there was no acceleration of *Betula pendula* pollination. Probably, the climate warming effect on the onset and duration in *Betula pendula* phenophases would be detectable in longer than a 16-year period.

Keywords

Betula pendula; pollination; climate warming; Poland; phenology

Introduction

According to the Intergovermental Panel on Climate Change (IPCC) [1], in the 1880–2012 period the average global temperature rose by 0.85°C and in the last decades the warming has increased significantly, at the rate of 0.13°C per 10 years. Several researches have pointed out the slight slowdown in the warming in the last years [2,3]. Forecasts indicate a 2–4°C rise in global temperature by the end of the twenty-first century. In Europe, the average temperature has increased, with regionally and seasonally variability. The greatest warming can be observed in Scandinavia, especially in winter. The average temperature over land area for the first decade of the twenty-first century was 1.3°C above the 1850–1899 average [4]. In Poland, the average annual temperature is characterized by a statistically significant warming trend at the rate of 0.2°C per 10 years and from the 80's an acceleration of warming has been observed [5–7]. The highest rising trend was in the spring (0.36°C/10 years) [7].

The global rise in air temperature causes a change in biosphere. It has major implications for the global carbon cycle, ecosystems, populations, individual species, shift in phenology, ecology of many living organisms (humans, plants, animals, fungi), public health, and economy [4,8–11]. Plants strongly respond to interannual climatic variation so they are good indicator of the global environmental change, especially warming [8,12–14]. During last decades the interest in phenology has been increased, resulting in many phenological researches [3,15–19]. In a temperate climate, the shifting of the spring and autumn phenophases is frequently observed, leading to the prolonged vegetative season. The beginning of flowering and leafing demonstrates the strongest acceleration [9,18,20]. The response to climate change depends on species and its ecotypes, ecological preference, the tolerance range for biotic and abiotic factors, phenophase [3,10,13,20–22]. Several species are sensitive to climate change and are used as climate-change indicator. Among them there are deciduous trees, herbaceous wild plants, and cereals [15,16,18,19]. Silver birch (*Betula pendula* Roth.) belongs to good phenological indicators and in many international or national phenological networks bud burst, beginning of flowering, leaf unfolding and leaf coloring are regularly observed [15,16,19,23,24]. In European aerobiological networks long-term observation of airborne *Betula* pollen is also conducted [10]. Almost all studies have demonstrated the shift of birch spring phenophases towards their earlier start. Juknys et al. [20] detected the negative impact of temperature on the timing of the bud burst and leaf unfolding in Lithuania. The earlier onset of flowering was detected in Lithuania by Veriankaitė et al. [25] and in the Czech Republic by Hájková et al. [26]. The acceleration of autumn phenophases like leaf coloring and fall was smoother [20]. Aerobiological investigations have shown the negative impact of climatic warming on birch pollen production and the onset of the pollen season in many countries in Europe [10,27,28].

In the light of global warming and numerous reports of its strong influence on plants, the study of *Betula pendula* phenophases against the background of temperature was undertaken. The thesis was put forward that pollination strongly depends on the temperature of the previous period and that there is an acceleration in the onset of pollination.

Material and methods

Study area

The investigations were carried out in the Rzeszów area, in Podkarpacie region, SE Poland, for 16 years (2000–2015). The city lies in the River Wisłok valley, 200–215 m above sea level, at a distance of several km from the Carpathian Plateau (300–600 m a.s.l.). The Rzeszów area is formed by a mosaic of forests and agricultural lands. The forest cover is 21.6%, while agricultural area 59.3%. Urban vegetation has been strongly anthropogenically transformed and many synanthropic plant communities are present in the study area [29]. In the city there are numerous green areas including urban lawns, gardens, parks, and recreational areas with ornamental plant species and urban trees (*Tilia* sp., *Acer* sp., and *Picea* sp.).

Climate and the weather in 2000–2015 in Rzeszów

The climate of this region is strongly influenced by transformed polar-maritime air masses. In the period 2000–2015, the mean annual precipitation was 676.7 mm and the average annual temperature 9.1°C. The warmest month was July (19.4°C) with the highest rainfall above 110 mm. August was also a warm month with an average temperature of 18.4°C. The coldest month was January (−1.9°C). The lowest rainfall was recorded in February and April, on average 31 and 27 mm, respectively (Fig. 1).

In the period of study, the climate parameters were characterized by a great variability. The annual temperatures were characterized by an increasing tendency (R^2 = 18.5%), but there was not statistically significant trend. A slight warming was detected in September and December. The polynomial function better describes the time-series change in average annual temperature showing the occurrence of a cyclical pattern. Two series of years with increasing temperature were noted: from 2003 to 2008 and from 2011 to 2015. There was a dramatic decrease in the years 2009–2010 (Fig. 2). As compared to the temperature, the fluctuation of rainfall was clearly higher with the coefficient of variation above 18%. Despite the lack of a statistically significant correlation between annual average temperature and annual total rainfall, in the coldest year (2010) with an average temperature of 8.2°C, rainfall was the highest (980 mm). The lowest rainfall (470 mm) was recorded in the warmest year (2015) with an annual average temperature above 10.2°C (Fig. 2).

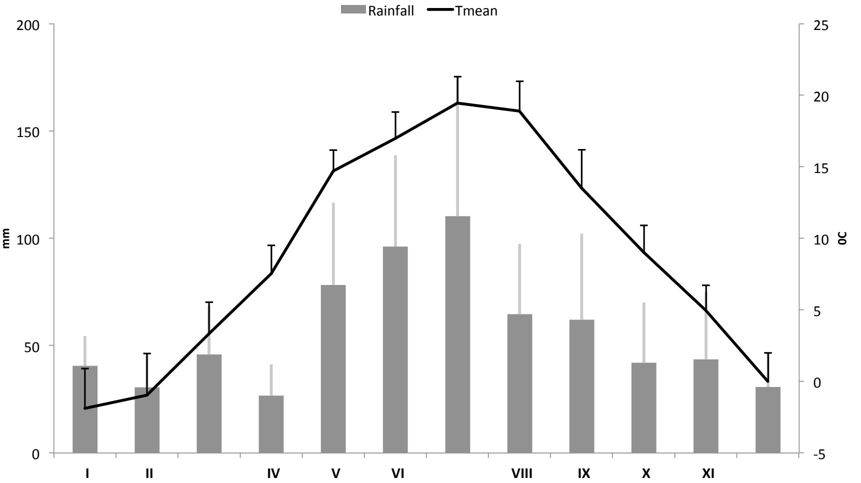

Fig. 1 Climatic diagram for Rzeszów for 2000–2015 (bars indicate standard deviations *SD*).

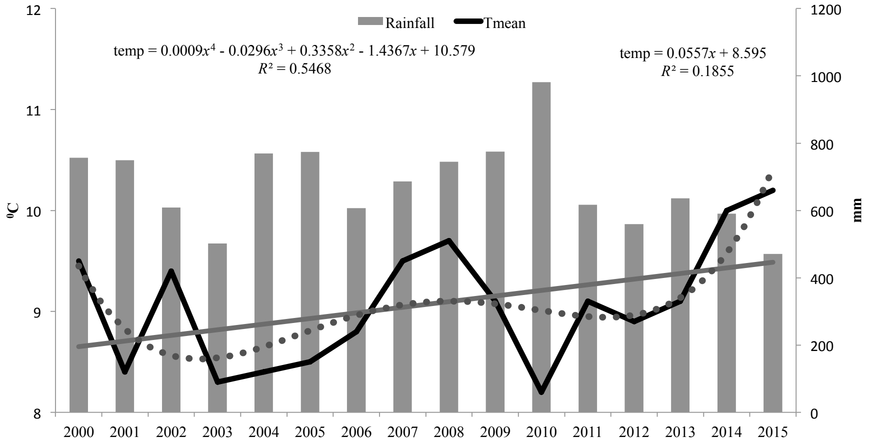

Fig. 2 Average mean temperatures and annual total rainfall in 2000–2015.

Phenological observations

The phenological observations were carried out each year from 1st of January until the end of the pollen release at several randomly selected locations. Based on the BBCH scale (Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie) [30] the dates of the start of pollination and the start of full pollination were noted (phenophases: BBCH 61, BBCH 65 respectively). Dates were expressed as the day of the year counted from 1 January (DOY).

The results were also expressed in a three-step scale calculated on the basis of quartiles (Q): (***i***) early start (E-start; the dates lower than Q1); (***ii***) typical start (T-start; the dates between Q1 and Q3); (***iii***) late start (L-start; the dates later than Q3).

Data analysis

To assess the strength and direction of the relationship between chosen meteorological parameters and the start of pollen and pollination season Pearson's correlation coefficient was applied. In this analysis, maximum, minimum and mean temperatures (°C) as well as total rainfall (mm) were included. The role of air mass circulation over Northern Atlantic, expressed as winter Hurrel index, was also estimated. Discriminate analysis was performed to detect which set of meteorological parameters discriminate years of early (E-start), late (L-start), or typical (T-start) dates of the investigated phenophases – BBCH 61, BBCH 65. The predictor variables (meteorological parameters) were not correlated. The number of independent variables must be less than the number of dependent variables (years), therefore, to complete this analysis, the meteorological factors for which correlation coefficients were significant and high have been considered. The statistical hypotheses were tested with $\alpha \leq 0.05$.

The weather data were obtained from the meteorological station in the airport Rzeszów-Jasionka, about 7 km northeast from the city. The values of North Atlantic Oscillation (NAO) index were obtained from https://climatedataguide.ucar.edu/climate-data/hurrell-north-atlantic-oscillation-nao-index-pc-based.

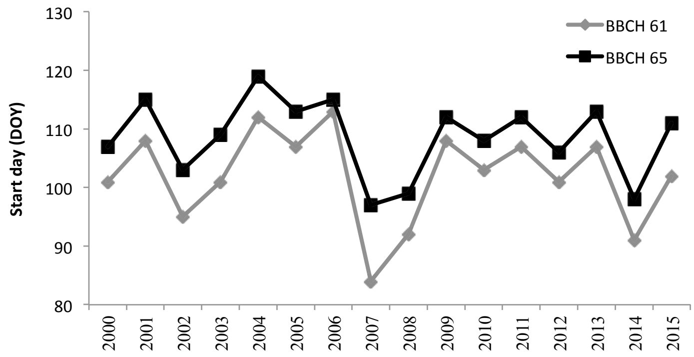

Fig. 3 The dates (DOY – days from 1 January) of the start of pollination and the start of full pollination phenophases (BBCH 61, BBCH 65) in 2000–2015.

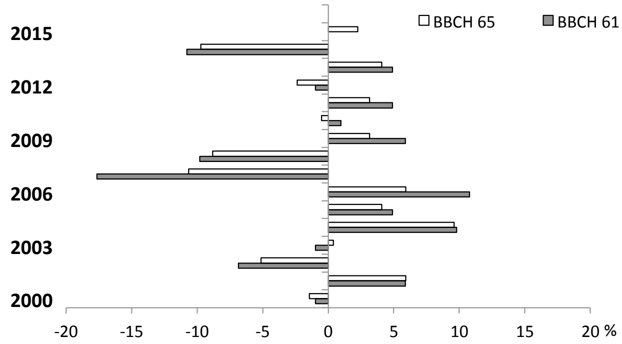

Fig. 4 Differences in the date of the start of pollination period (BBCH 61) and the start of full pollination period (BBCH 65) in relation to mean values for 2000–2015.

Tab. 1 The dates of the start of pollination period (BBCH 61) and the start of full pollination period (BBCH 65) of *Betula pendula* (Roth.) in 2000–2015 years.

Phenophases	Mean date	The earliest date in year	The latest date in year
BBCH 61	12 April	25 March / 2007	23 April / 2006
BBCH 65	18 April	7 April / 2007	29 April / 2004
Duration of BBCH 61 (in days)	7	2/2006	13/2007

Results

In the Rzeszów area, silver birches started to pollinate (BBCH 61) in the middle of April and this phenomenon was characterized by low variability *V* = 7.8% (Fig. 3, Fig. 4). The difference between the earliest and latest dates was nearly a month (Tab. 1). In 2002, 2007, 2008, and 2014 the silver birch started to pollinate very early (E-start), e.g., earlier than 4 April. In 2001, 2004, 2006, and 2009 very late (L-start) pollination was observed (it started after 17 April). In 2000, 2003, 2005, 2010–2013, 2015 (T-start) silver birch began to pollinate between 10 and 16 April (Fig. 3, Fig. 4).

The BBCH 61 phenophase lasted an average of 7 days with a minimum of 2 days and a maximum of 13 days (Tab. 1). It has been found that the period lasted longer when the pollen release started earlier ($r = -0.713$). The trend was particularly evident in 2006, 2007, and 2009. In 2006, the pollination started at the latest and lasted only 2 days. Next year, a converse relationship was found (Tab. 1, Fig. 4, Fig. 5).

The period of full pollination (BBCH 65) started on average on 18 April and the variability in its dates was lower (V = 6%) in comparison to BBCH 61 (Tab. 1). In early years (E-start; 2002, 2007, 2008, 2014) this phenophase began before 13 April and in late years (L-start; 2001, 2004, 2005) after 24 April. The range 16–22 April was characteristic for typical years (T-start; Fig. 3, Fig. 4).

The dates of phenophases were characterized by variation, but the variation coefficients were not so high. In 2000–2015, the temperature varied cyclically but showed an upward tendency. Despite this, there was no statistically significant trend or no tendency also in terms of flowering (Fig. 2).

It has been demonstrated that the course of weather had a significant impact on the start of pollination and the start of full pollination period. The crucial was the course of weather in January, February, and March. The air temperature was the most important factor affecting dates of the phenophases. The relationships were negative and the modules of the correlation coefficients were above $|r| = 0.5$, but for the first half of March above $|r| = 0.68$. The dates of BBCH 61 and BBCH 65 also depended on annual temperature, with average $|r| = 0.58$. Rainfall, but only in December in the previous year, impacted on the start of pollination (BBCH 61). The beginning of pollen release also depended on air mass circulation over North Atlantic Oscillation in "winter" months. The positive NAO in March and from December to March resulted in an earlier start of *Betula pendula* pollination. The temperatures in January, February, and March positively affected also the duration of BBCH 61 (Tab. 2). The temperature of the previous year did not significantly affect the phenology, however, there was a tendency for delayed dates under the influence of higher temperature in October–December.

Considering the synergistic impact of meteorological parameters, years with an early (E-start), late (L-start), and typical start (T-start) of pollination (BBCH 61) could be distinguished. Root 2 evidently differentiates years with typical dates (T-start; Fig. 6). The most important were temperature and rainfall in January and February, rainfall in March, and temperature just before the pollination, e.g., in the first half of March.

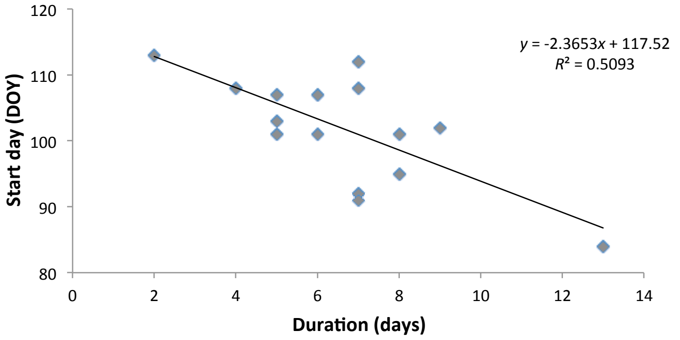

Fig. 5 The relationship between the start and the duration of BBCH 61 phenophase (the start of pollination period).

Tab. 2 The values of the Pearson correlation coefficients (r) and linear regression functions.

Meteorological parameters	Start of the pollination period (BBCH 61)	Start of the full pollination period (BBCH 65)	Duration of BBCH 61 phenophase
$T_{\text{max I}}$	$r = -0.610$; $= 103.26 - 1.805 \times T_{\text{max I}}$	NS	$r = 0.692$; $= 6.131 + 0.617 \times T_{\text{max I}}$
$T_{\text{min I}}$	$r = -0.609$; $= 93.833 - 1.611 \times T_{\text{min I}}$	$r = -0.503$; $= 103.09 - 1.080 \times T_{\text{min I}}$	$r = 0.667$; $= 9.256 + 0.531 \times T_{\text{min I}}$
$T_{\text{mean I}}$	$r = -0.619$; $= 98.617 - 1.783 \times T_{\text{mean I}}$	$r = -0.516$; $= 106.27 - 1.208 \times T_{\text{mean I}}$	$r = 0.663$; $= 7.654 + 0.575 \times T_{\text{mean I}}$
$T_{\text{max II}}$	$r = -0.551$; $= 105.13 - 1.395 \times T_{\text{max II}}$	NS	$r = 0.517$; $= 5.676 + 0.395 \times T_{\text{max II}}$
$T_{\text{mean II}}$	$r = -0.547$; $= 100.56 - 1.505 \times T_{\text{mean II}}$	$r = -0.502$; $= 107.49 - 1.123 \times T_{\text{mean II}}$	NS
$T_{\text{max III}}$	$r = -0.702$; $= 117.95 - 1.964 \times T_{\text{max III}}$	$r = -0.669$; $= 120.92 - 1.522 \times T_{\text{max III}}$	$r = 0.524$; $= 2.973 + 0.442 \times T_{\text{max III}}$
$T_{\text{min III}}$	$r = -0.630$; $= 98.548 - 2.662 \times T_{\text{min III}}$	$r = -0.596$; $= 105.91 - 2.047 \times T_{\text{min III}}$	NS
$T_{\text{mean III}}$	$r = -0.717$; $= 110.67 - 2.604 \times T_{\text{mean III}}$	$r = -0.680$; $= 115.24 - 2.007 \times T_{\text{mean III}}$	$r = 0.545$; $= 4.573 + 0.597 \times T_{\text{mean III}}$
$T_{\text{max 1–15 III}}$	$r = -0.682$; $= 110.89 - 1.442 \times T_{\text{max 1–15 III}}$	$r = -0.6317$; $= 115.24 - 1.082 \times T_{\text{max 1–15 III}}$	$r = 0.5646$; $= 4.347 + 0.358 \times T_{\text{max 1–15 III}}$
$T_{\text{min 1–15 III}}$	$r = -0.692$; $= 97.381 - 1.863 \times T_{\text{min 1–15 III}}$	$r = -0.6353$; $= 105.11 - 1.391 \times T_{\text{min 1–15 III}}$	$r = 0.5818$; $= 7.733 + 0.472 \times T_{\text{min 1–15 III}}$
$T_{\text{mean 1–15 III}}$	$r = -0.702$; $= 105.19 - 1.771 \times T_{\text{mean 1–15 III}}$	$r = - 0.6447$; $= 110.92 - 1.309 \times T_{\text{mean 1–15 III}}$	$r = 0.6132$; $= 5.731 + 0.473 \times T_{\text{mean 1–15 III}}$
$\text{NAO}_{\text{I–III}}$	$r = -0.516$; $= 102.54 - 3.301 \times \text{NAO}_{\text{I–III}}$	NS	NS
NAO_{III}	$r = -0.532$; $= 102.12 - 2.443 \times \text{NAO}_{\text{III}}$	NS	NS
$\text{R}_{\text{XII}\ n-1}$	$r = 0.582$; $= 97.530 + 0.098 \times \text{R}_{\text{III}}$	NS	$r = -0.580$; $= 8.107 - 0.033 \times \text{R}_{\text{III}}$

T – temperature; R – rainfall; Roman letters – months; $n-1$ – previous year; NS – not statistically significant.

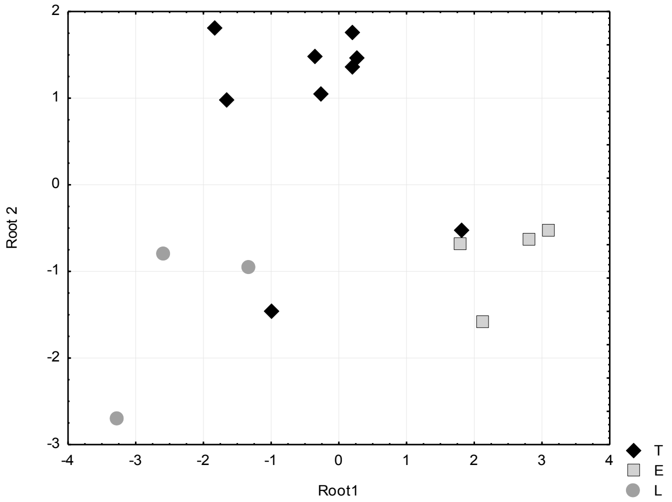

Fig. 6 Discriminate analysis for categories of BBCH 61 (the start of pollination period) and meteorological parameters (T_{max}, T_{min}, T_{mean}; rainfall in January and February; rainfall in March; T_{max}, T_{min}, T_{mean} in 1–15 March); E, T, L: early, typical, and late start dates; Root 1, Root 2 – the discriminant functions.

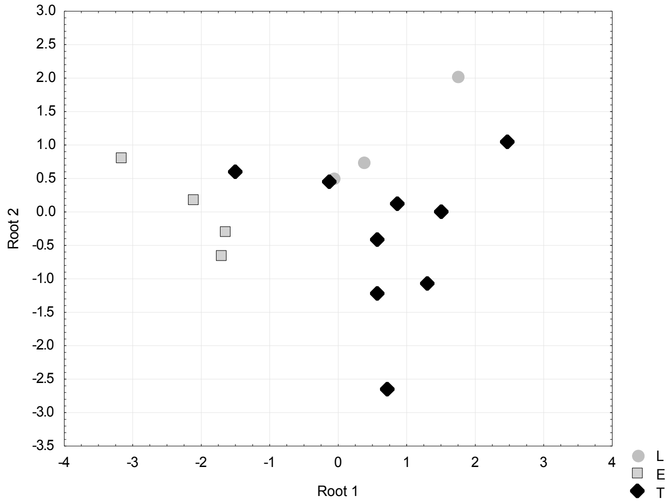

Fig. 7 Discriminate analysis for categories of BBCH 65 (the start of full pollination period) and meteorological parameters (T_{max} in February; rainfall in March; T_{max}, T_{min}, T_{mean} in 1–15 March); E, T, L: early, typical, and late start dates; Root 1, Root 2 – the discriminant functions.

Regarding BBCH 65, Root 1 clearly discriminates the category of early start (E-start) and the other categories of typical (T-start) and late start (L-start) (Fig. 7). The synergistic influence of maximum temperature in February, rainfall in March as well as maximum, minimum, and mean temperatures during the first half of March impacted on the results. When single meteorological parameters were considered, the rainfall in the period before pollination did not affect the dates of the investigated phenophases.

Discussion

Phenological observations of *Betula pendula* have been conducted in many European countries. The variability of timing in phenophases reported on the basis of multi-year observations reveals a tendency for an acceleration in the onset of the pollen season, flowering, or leaf unfolding [10,16,18–20,31]. The obtained results showed considerable interannual differences in the onset of flowering phenophases (BBCH 61, 65) and in the duration of interphase interval in the Rzeszów area. During the 16 years of observations, in over 50% of this period, flowering (BBCH 61) began on a typical date. During 3 years, the onset of flowering was delayed, but in 4 years it was accelerated. The BBCH 65 phenophase was characterized by a similar tendency. The type of climate determined the onset and course of many phenological phenomena. In mountain regions, where the annual average temperature is clearly lower than in the lowlands, the phenophases of many species can be delayed by as much as a month [19,31]. Hájková et al. [26] conducted phenological observation in Lednice (the Czech Republic), where climate conditions are very similar to those in Rzeszów. In both regions, July is the warmest month with temperature above 19°C and January is the coldest month with temperature below −1°C. The lowest rainfall is in February and the highest in June and July. Because of the same climate conditions, the results can be compared and the analyses showed pronounced similarity in the onset of spring phenophases of silver birch. On average, in Lednice silver birch started to flower on 8 April but in Rzeszów 4 days later. In both cities the earliest dates were at the end of March, whereas the latest ones on 18 April in Lednice and 23 April in Rzeszów. The dates of the beginning of the full flowering phase were also very similar. In Lednice, the average date was 12 April and in Rzeszów 6 days later. Summarizing, the differences in the dates of the flowering phenophases were less than 1 week on average. In both cities the average periods between the beginning of the flowering and the full flowering phases were very short, e.g., 7 days in Lednice and 4 days in Rzeszów, with the minimum of 1 and 2 days and the maximum 11 and 13 days, respectively. Towards the north, birches pollinate later. In Lithuania, the spatial variation of the start of flowering was considerable, differences could reach 24 days, and the values of the variation coefficients did not exceed 9%. Generally, *Betula pendula* started to flower at the beginning of May, with a tendency to significantly accelerate [14,25]. If birch flowering came earlier, the difference between the earliest and the latest flowering of plants in Lithuania increased. Towards the north, the variability was even more pronounced. In the 60s in southern Finland, the flowering started in late April, and in northern Finland 2 months later. It was observed that there were even years with no flowering, especially in regions with a very harsh climate [32].

The trend to advance spring phenophases is observed commonly in the Northern Hemisphere, which is partly explained by the rising temperature in March and May [7,20]. In Ireland, out of 61 species, 45 showed earlier spring events, concerning bud burst, leaf unfolding, and flowering [8]. In Lithuania in the 70s, *Betula* species started to flower mainly in May, and in the 90s in late April and the average advance was 10–15 days. At the beginning of the twenty-first century (2004–2008) birches flowered even in the middle of April [14,25]. The authors showed warming as a cause of this. According to their modeling, in the twenty-first century the flowering will accelerate approximately 20 days, and in a pessimistic scenario, it could be nearly two months. An increase in temperature of 1°C will result in 8-day shift [25]. The acceleration of flowering was also shown by Hájková et al. [19,26,31] for the Czech Republic. They compared last two decades, and clear acceleration was found in the second one. In Rzeszów, SE Poland, during the 16 years of observation no trend or even a slight tendency were observed. In fact, over the period of study, the onset of birch flowering was characterized by fluctuation, not acceleration. Are the results not consistent with the general trend? Firstly, warming does not occur at a constant rate and the trends can be proved only on the basis of decades of monitoring [1,4]. Additionally, in recent years the rate of increase has slowed [2,3]. In Rzeszów, observation was conducted over 16 years, which was probably not enough to detect any tendency. In Rzeszów, in 1951–2005, the rising trend was significant, with $R^2 = 11.8\%$ [6], but in the period of study the annual and monthly temperatures fluctuated without a significant tendency. Juknys et al. [20] observed great variability of birch spring phenophases, and only on the basis of 50 years of study they detected a statistically significant negative trend. Secondly, phenological phenomena do not always accurately reflect warming and potential changes can occur later. In Rzeszów, the increase of annual temperature was slight and climatic conditions did not strongly affect silver birch. Generally, climate forcing is detectable in spatial scale, in local conditions the response to weather is more pronounced.

Most phenological observations have demonstrated that warming has caused substantial changes in life cycle of many organisms and an acceleration in the timing of many phenophases is forecast. The question arises whether there are any limits to this acceleration. It has been shown that pollen production can be limited by increasing temperatures and therefore it has been hypothesized that continuous warming could decrease pollen production and shorten the pollen season [10,28]. Newhman et al. [28] and Sparks et al. [33] as well as several other authors [3,34] suggested that the day length might be the limiting factor for advancement of the start of flowering or pollen season.

Betula species, as many spring flowering plants, strongly react to the weather course. In late summer and early autumn, trees enter the endodormancy phase, which is controlled by internal mechanisms. After a necessary chilling period, plants enter the ecodormancy controlled by external factors like weather. Rising temperature breaks dormancy and that is why this meteorological parameter most strongly affects the onset of spring phenophases [9,24,28,35]. Warm spring accelerates the growing season of many plants, and it is clearly pronounced for plants flowering in early spring, which require less chilling [3]. Menzel et al. [36] as well as Juknys et al [20] claimed that in Europe the accelerations of spring phenophases were the result of the increasing temperature in February and March. The results of my study showed that temperature affected flowering more strongly than rainfall. The most important was the temperature in weeks preceding the onset of flowering, especially in the first half of March. The correlation was significant and the linear regression models explained the relationship quite well. In Rzeszów, temperatures of the previous year did not affect the onset of pollination, but the tendency towards later flowering due to a warm autumn and winter was detected. In fact, the influence of temperature on life cycle is divergent [13,22]. Warming during endodormancy delays the dormancy break and more chilling is required for the start of vegetation. Late or missing chilling may delay or even inhibit life cycle [9,20,28,35]. Therefore, the relationship between temperature and the timing of spring phenophases is not strictly linear, and despite the tendency to advanced phenological phenomena, there are species whose phenological events are delayed [22]. The significance of rainfall is difficult to assess and interprete. It seems that in Rzeszów rainfall did not directly affect the observed phenomena. A similar conclusion was presented by Hájková et al. [26]. Nevertheless, the analysis revealed the certain significance of rainfall in December in the previous year. Temperature and rainfall in February and March were found to have a synergistic effect on the investigated events. NAO strongly influences the temperature in Europe. The positive phases in winter and spring months are associated with moist and warm winter, which promotes the onset of vegetation. Numerous studies have demonstrated a strong association of air-mass circulation over the Northern Atlantic and the start of several phenological events [37]. In Rzeszów, the positive NAO index for spring months was correlated with the earlier start of pollination.

Conclusions

In the Rzeszów area, *Betula pendula* started to pollinate in mid-April and 1 week later the full pollination period began. The onset of flowering fluctuated and, in contrast to most of the literature data, no acceleration was detected. Presumably, the acceleration of flowering trend in response to climate warming cannot be excluded, however, 16 years of observations is too short a period to detect it. To assess the global shift in the timing of phenophases, long-term observations are necessary, because the increase of temperature is not linear. The air temperature in spring season as well as temperature and rainfall in the first decade of March are particularly important for the onset and duration of *Betula pendula* phenophases. In the future, the analysis should also be focused on temperature patterns in autumn and winter.

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Zmienność początków pylenia *Betula pendula* (Roth.) w Rzeszowie, w południowo wschodniej Polsce: fluktuacje czy trend?

Streszczenie

Większość badań klimatycznych wskazuje na wyraźny wzrost temperatury w skali globalnej. Ocieplenie klimatu znacząco wpływa na organizmy żywe i ich cykle życiowe, ekosystemy, człowieka i gospodarkę. Rośliny silnie reagują na zmiany środowiskowe, w tym szczególnie na wahania temperatury powietrza, stąd są dobrym indykatorem zmian klimatycznych. Jedną z takich roślin jest brzoza brodawkowata *Betula pendula* Roth. Celem badań była weryfikacja założenia o przyśpieszeniu pylenia brzozy brodawkowatej. Badania przeprowadzono w Rzeszowie, w SE Polsce w latach 2000–2015. W tym czasie brzoza brodawkowata rozpoczynała pylenie w połowie kwietnia, a różnica między najwcześniejszym a najpóźniejszym terminem wyniosła prawie miesiąc. Okres pełni pylenia rozpoczynał się średnio 18 kwietnia. Terminy te silnie zależały od przebiegu pogody w lutym i marcu, a kluczowa była temperatura w pierwszej połowie marca. Rozpatrując synergiczne oddziaływanie parametrów meteorologicznych najbardziej istotne były temperatury i opady w styczniu i lutym, opady w marcu oraz temperatura w pierwszej połowie marca. Stwierdzono również wpływ Oscylacji Północnoatlantyckiej na badane zjawiska. W latach objętych badaniami roczne temperatury wykazały nieznaczną tendencję wzrostową, jednak nie stwierdzono istotnych statystycznie trendów czy nawet słabych tendencji w terminach pylenia. Początek pylenia charakteryzował się fluktuacją a nie przyspieszeniem.